AIR FORCE

QUALIFICATION TRAINING PACKAGE

(AFQTP)

for

HVAC/REFRIGERATION

(3E1X1)

MODULE 11

TOOLS AND TEST EQUIPMENT

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MODULE 11

TOOLS AND TEST EQUIPMENT

Career Field Education and Training Plan (CFETP) references from 1 Apr 97 version.

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INTRODUCTION

Before starting this AFQTP, refer to and read the "Trainee/Trainer Guide" located on the AFCESA Web site **http://www.afcesa.af.mil/**

AFQTPs are mandatory and must be completed to fulfill task knowledge requirements on core and diamond tasks for upgrade training. ***It is important for the trainer and trainee to understand*** that an AFQTP ***does not*** replace hands-on training, nor will completion of an AFQTP meet the requirement for core task certification. AFQTPs will be used in conjunction with applicable technical references and hands-on training.

AFQTPs and Certification and Testing (CerTest) must be used as minimum upgrade requirements for Diamond tasks.

MANDATORY minimum upgrade requirements:

Core task:
AFQTP completion
Hands-on certification

Diamond task:
AFQTP completion
CerTest completion (80% minimum to pass)

Note: *Trainees will receive hands-on certification training for Diamond Tasks when equipment becomes available either at home station or at a TDY location*.

Put this package to use. Subject matter experts, under the direction and guidance of HQ AFCESA/CEOT, revised this AFQTP. If you have any recommendations for improving this document, please contact the HVAC/R Career Field Manager at the address below.

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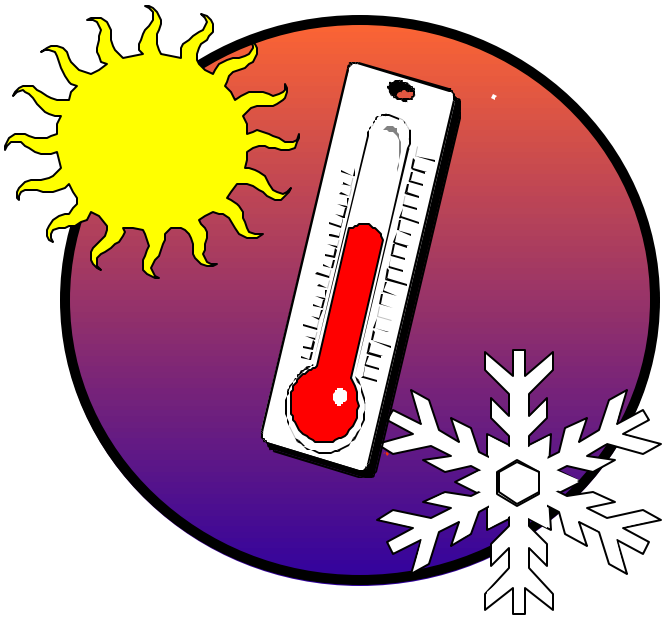
Notice. This AFQTP is *NOT* intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.



TOOLS AND TEST EQUIPMENT

MODULE 11 AFQTP UNIT 1

MAINTAIN AND USE TOOLS (HAND AND POWERED) (11.1.)

Notice. This AFQTP is *NOT* intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.

MAINTAIN AND USE TOOLS (HAND AND POWERED)

Task Training Guide

STS Reference Number/Title:	11.1. Maintain and Use Tools (hand and powered)
Training References:	• TR: AFI32-1064; T.O.s 32-1-101, 33A1-12-2-1
Prerequisites:	• Possess as a minimum a 3E131 AFSC.
Equipment/Tools Required:	• Goggles/Leather gloves • PPE • Standard HVAC/R Tool Bag
Learning Objective:	• The trainee will know the steps required to safely maintain and use tools (hand and powered)
Samples of Behavior:	• Trainee will be able to safely maintain and use tools (hand and powered)
Notes:	
• Any safety violation is an automatic failure.	

MAINTAIN AND USE TOOLS (HAND AND POWERED)

Background: The purpose of this section is to instruct you in the proper use of hand tools and shop equipment and how to use the hand tools and shop equipment.

The first thing we need to talk about is shop safety and proper working methods.

Horseplay. Some of the common varieties of horseplay are pushing, tripping, directing compressed air toward a friend, shocking a friend with electricity, applying a hotfoot, and perhaps the worst of all -- goosing. This goosing, if applied to a nervous person, may cause him to leap into moving machinery or into contact with an electrical circuit.

Proper Working Methods. Equipment that has exposed moving parts, such as belts, chains, flywheels, moving arms, etc., can be a serious safety hazard unless care is exercised during its operation and maintenance. While most moving parts of machinery are enclosed in protective guards, alertness on the part of the operator or mechanic is essential. *Gloves, neckties, or loose clothing, particularly large loose sleeves, should not be worn around moving machinery*. Visualize, for a moment, what would happen if your necktie or your sleeve should become caught in a drive belt or chain. You would be lucky to escape with your life.

Any adjustment, cleaning, lubrication or repair of moving machinery should be accomplished with the device stopped if possible. If it is not possible to stop the device, extreme care should, and must be observed to prevent serious injury.

Hazardous Noise. It is important to realize that sound of moderate intensity, encountered for prolonged periods, can be as injurious to your hearing as high intensity sound encountered for a short period of time.

Most of the time a hazardous noise condition will not cause your ear's pain, so you are not immediately aware that your hearing is being damaged.

Earplugs are about as simple a safety device as you will ever see. Do not let the simplicity of earplugs detract from their value. If properly used, they will save your hearing. Expect to use these without fail when working in an area where the noise level is continuously high, such as a diesel powerhouse, a boiler plant or a centrifugal air conditioning equipment room. In some cases, if the ear plugs bother your ears, ear muffs are provided as protection from hazardous noise.

Use of Tools. Common tools you will use throughout your career include:

Screwdrivers. Screwdrivers are one of the most commonly used hand tool. They are used to remove or replace screws. There are three types of screwdrivers that we will be discussing, they are the standard, cross slot, and offset screwdrivers.

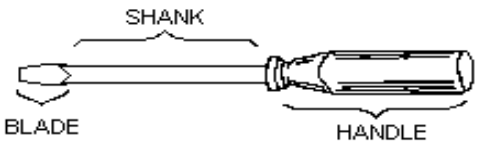


Figure 1, **Standard Screwdriver**

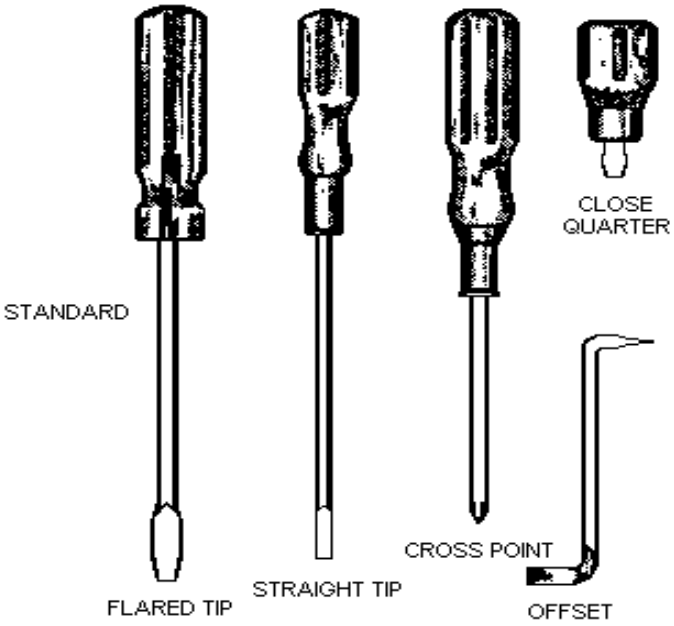


Figure 2, Flare Tip and the Straight Tip

Standard (Common) Screwdriver (Figure 1). Screwdrivers are usually identified by size according to the combined length of the shank and blade. Measure the screwdriver from the base of the handle to the tip of the blade--This gives the screwdriver size. Common sizes are: 3", 4", 5", 6", 8", 10" and 12". There are two different styles of standard screwdrivers: the flare tip and the straight tip (Figure 2).

The common screwdriver blade must be straight and have sharp corners that fit the screw slot firmly. You will not damage a screw head if you use the right size screwdriver. Hold the screwdriver firmly against the screw to prevent it from slipping. Do not hold the screw in your hand while applying pressure to tighten it. If the blade should slip, you could damage your work or seriously injure your hand. **Always keep safety first and foremost in your mind**. Never use a screwdriver as a chisel or pry bar because the tip is hard and may break (See Figure 3).

When the blade tip becomes rounded or broken, you can usually restore it to the original shape with a bench grinder or file.

When using a screwdriver to apply torque, pressure should be exerted straight down on the handle as shown in Figure 3. When selecting a screwdriver for use, select the largest blade that will fit the screw slot.

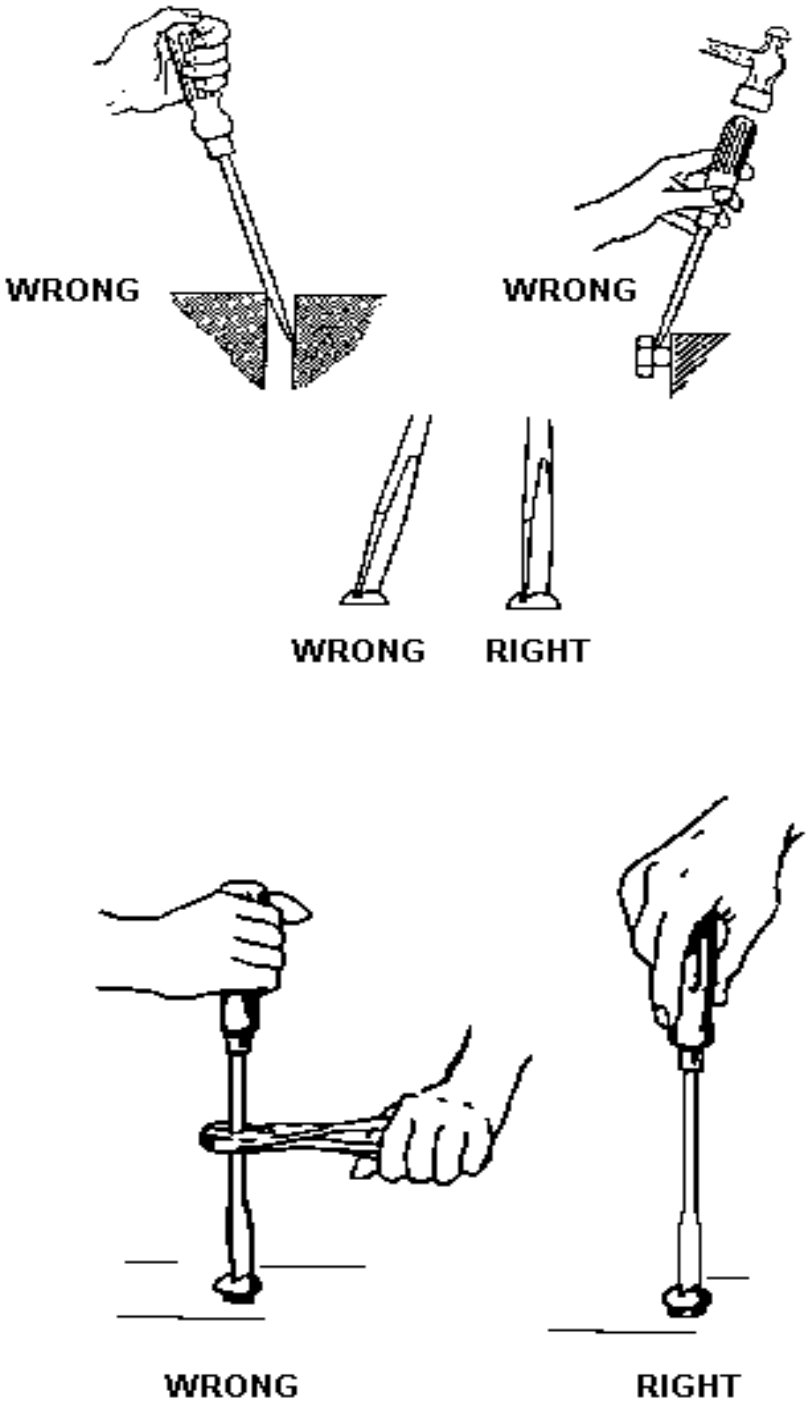


Figure 3, Proper Selection

Too much emphasis cannot be placed on selecting a screwdriver that fits the screw slot. Figure 4 will aid you in selecting the correct size screwdriver.

A screwdriver of the correct size for the screw slot will prevent marking of the blade tip, prevent breaking or bending the tip of the blade, reduce the force required to keep the screwdriver in the slot, and prevent damage to the screw slot. Remember, there is a proper size screwdriver for every job.

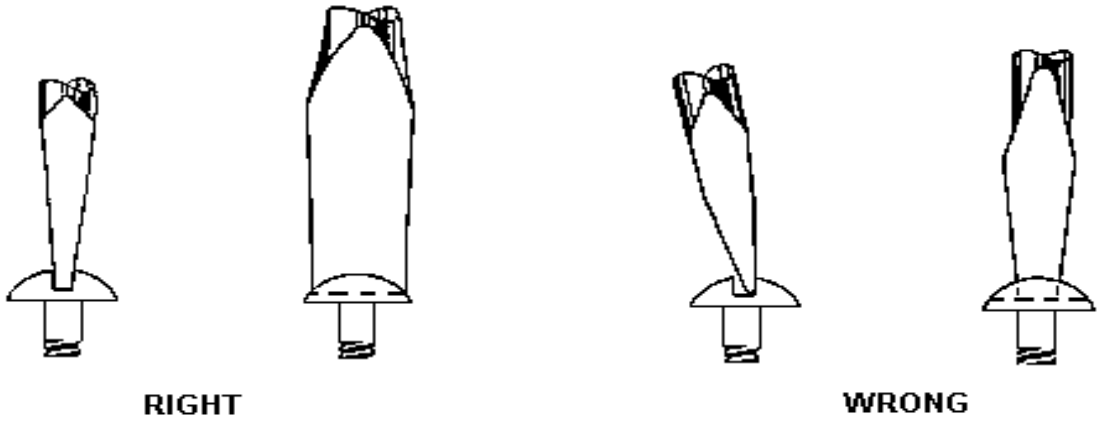


Figure 4, Selecting correct size

Cross-Slot (Cross-Point) Screwdriver. The cross-slot or cross-point screwdriver comes in about the same sizes as the common screwdriver. You must apply the proper size to the screw or you may damage both the screw and the screwdriver. There are two main types of cross-point screwdrivers: the Phillips and the Reed and Prince.

- **Phillips.** The Phillips cross-point screwdriver has a blunt blade.
- **Reed and Prince.** The Reed and Prince cross-point screwdriver is much like the Phillips, except it has a sharp or pointed blade and is used on pointed cross-slot screws. (See Figure 5). The Phillips screwdriver should only be used on Phillips head screws. The Reed and Prince screwdriver should only be used on Reed and Prince screws.

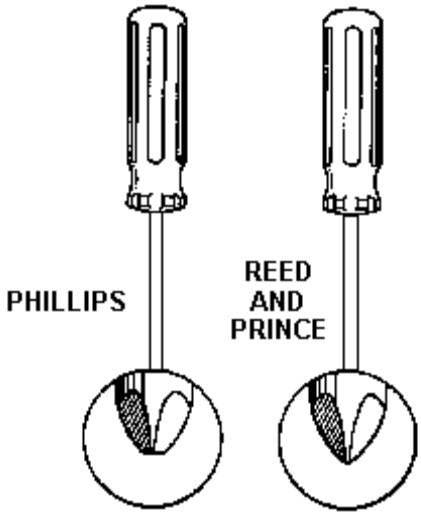


Figure 5, Phillips and Reed and Prince

Offset. The offset screwdriver is a very handy item for the HVAC/R specialist since you use it to turn screws at remote, hard-to-get-at-angles. It has a shank about 5 inches in length, with blades on each end bent to about 1/2 inch. The blades are bent at 90´ angles so that they can be used to reach remote locations. (Refer to Figure 6)

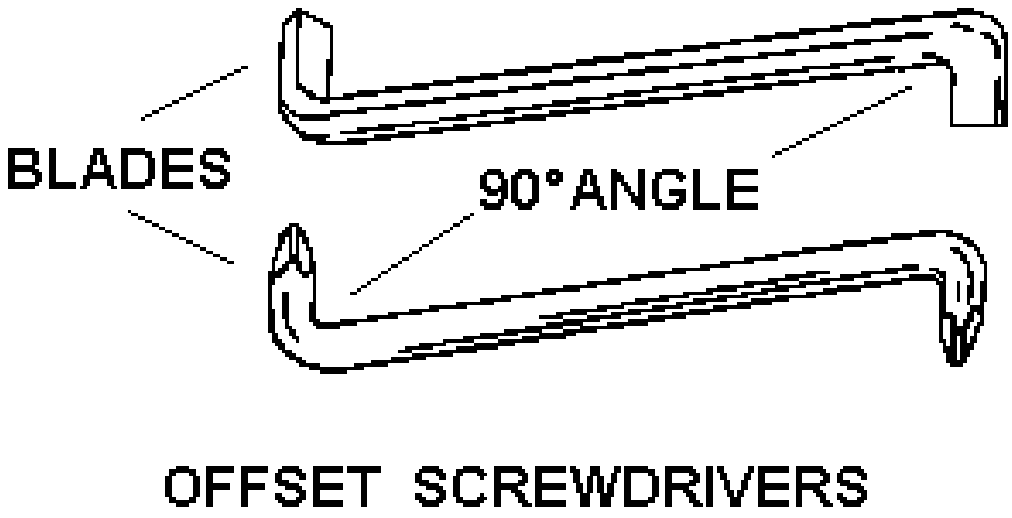


Figure 6, Offset Screwdrivers

Pliers. Each pair of pliers is designed for a specific job. There are cutting, gripping, or holding types, consisting mainly of a pair of jaws, a pivot point and a pair of handles. The various types of pliers that you normally use are shown in Figure 7.

- **Cutting Plier.** The side cutting (lineman's) pliers and diagonals are of the cutting types. The diagonals are for close cutting, while the side cutters are used for much heavier cutting of larger wire and small cables.

- **Gripping Pliers.** The combination slip-joint and water pump pliers are used extensively in mechanical work. They are used to grip pipes and bolts.

  Long nose pliers also serve many useful purposes. They may be used to bend an eye or loop in solid wire so that it can be wrapped around a bolt or screw head. In places where you cannot get your fingers to tighten small size nuts or bolts, the proper application of the long nose pliers will be helpful. The long nose pliers act as extensions of your finger in many instances.

  The various lengths and shapes of flat nose, round nose, and half-round nose pliers make it possible to bend or form metal into a variety of shapes. They also allow the work to be done in close quarters.

Holding Pliers. Another type of pliers commonly used is the clamp pliers, known more commonly as vise grips. This tool is a combination of a wrench, a plier, and a vise. Clamp pliers (vise grips) are adjusted to various jaw openings and then locked in position. This type of plier is greatly misused. You should always use the correct tool for the correct job.

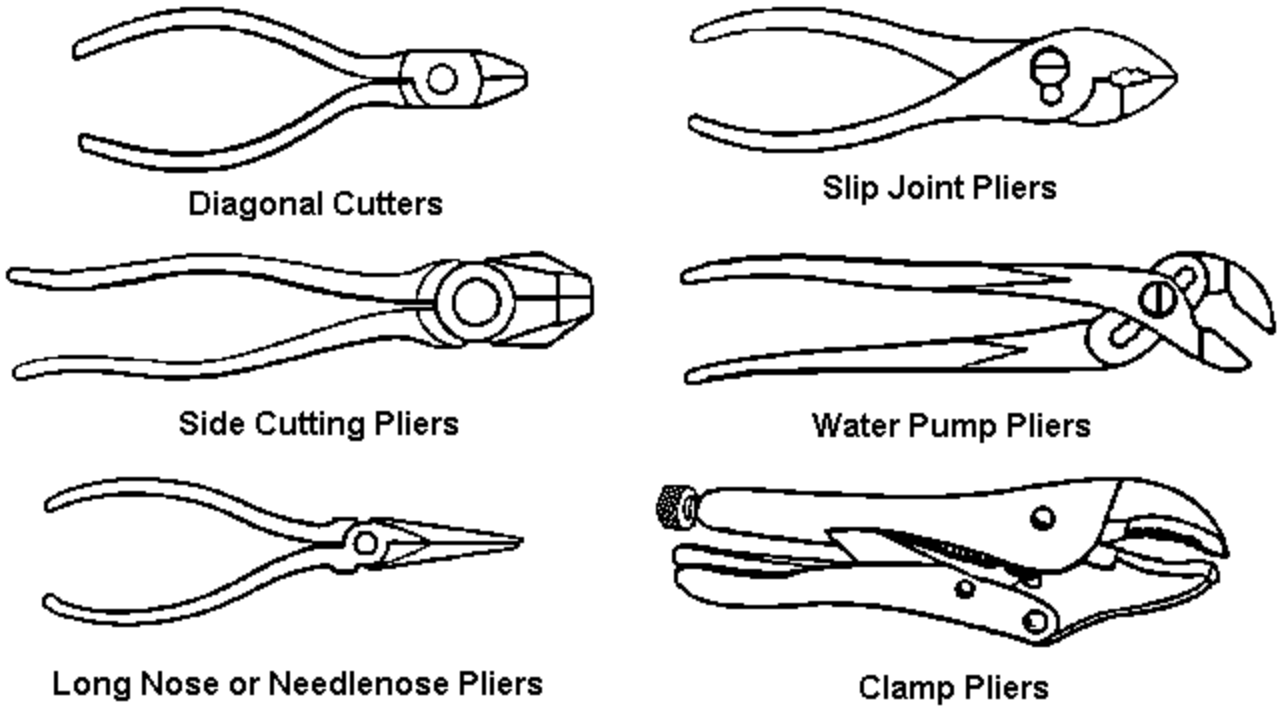


Figure 7, Types of Pliers

Pliers require an occasional light oiling at the pivot point or joint. Cutting pliers at times may become pitted at the cutting edge. Here again the proper application of a fine file over a pitted spot on the cutting edge is sufficient to restore its original condition. You can also use the fine file to sharpen the cutting edge of the diagonals or side cutters if necessary.

The hinge or joint of water pump and slip-joint pliers may occasionally require a drop of oil and tightening of the hold nut. The knurled jaws or gripping teeth of these tools require cleaning for better gripping. Use a steel brush to clear out steel wastes, paints, and grease that have accumulated in the teeth or knurled jaws.

Pliers are often misused by the tradesman, especially as a wrench or pry bar. Pliers should never be used to tighten a nut (See Figure 8). This normally damages the nut badly enough that you will probably not be able to get a wrench back on the nut. You should never use pliers as a pry bar. Their handles may bend or break, rendering them useless.

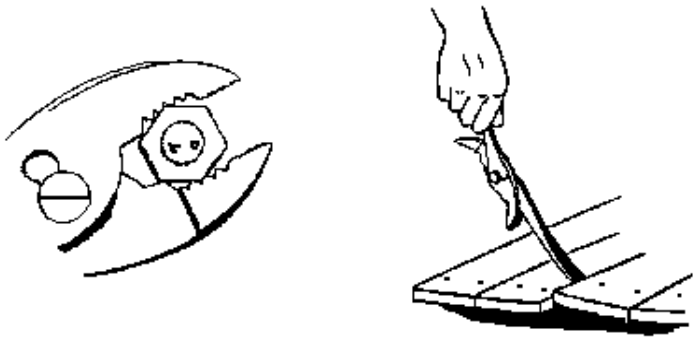


Figure 8, Common Misuses of Pliers

Hammers. There are several different types of hammers for different jobs. You may be called upon to use any one of the hammers shown in Figure 9. There are two hammers used by the HVAC/R mechanic most often. One is the machinist or ball peen hammer, and the other is the claw hammer. It is important to use these tools properly. Use the ball peen hammer to strike such items as caulking irons and chisels; use the claw hammer to drive and pull nails.

To prevent rust from forming, carefully wipe steel hammer heads dry after exposure to moisture. *When using any hammer, large or small, be sure the head is properly secured to the handle*. If wedges in the end of the handle loosen, remove them, and install larger wedges. If the wedge remains tight in the handle, but the handle loosens, drive a thin hardwood iron wedge into the handle beside the original wedge. A loose handle can be temporarily repaired by soaking it in water. If the handle becomes worn or cracked or if it cannot be tightened, replace it.

Wrenches. Wrenches are tools used for tightening and removing nuts, bolt heads, and cap screws. They are also used for gripping round items, such as pipe, studs, and round rods. Wrenches are generally classified as adjustable jaw wrenches, socket wrenches, open-end wrenches, box-end wrenches, and pipe wrenches.

- **Pipe Wrench.** Pipe wrenches range in size from 6 to 60 inches. The offset wrench may be as long as 36 inches. (See Figure. 10). Pipe wrenches are used for turning pipe, round rod, and smooth fittings that do not offer a gripping surface for other types of wrenches; however, the bit of the jaws mars the work. Pipe wrenches should not be used on nuts or bolts.

  When using a pipe wrench be sure the teeth on the jaws are clean and sharp. When the teeth become dull, they can be sharpened with a file. When they become worn out, they can be replaced by inserting a new hook jaw and a heel jaw.

  The housing or main body of the wrench is made very strong and will withstand tremendous strain, but DO NOT use a pipe extension on the handle; use a larger wrench. Only a pipe wrench that is in good condition should be used. If you cannot get parts, the wrench should be taken out of service immediately. Keep the threads on the hook jaw and nut cleaned and oiled.

  NOTE:
  Never use pipe wrenches on square or hexagon-shaped objects except pipe unions.

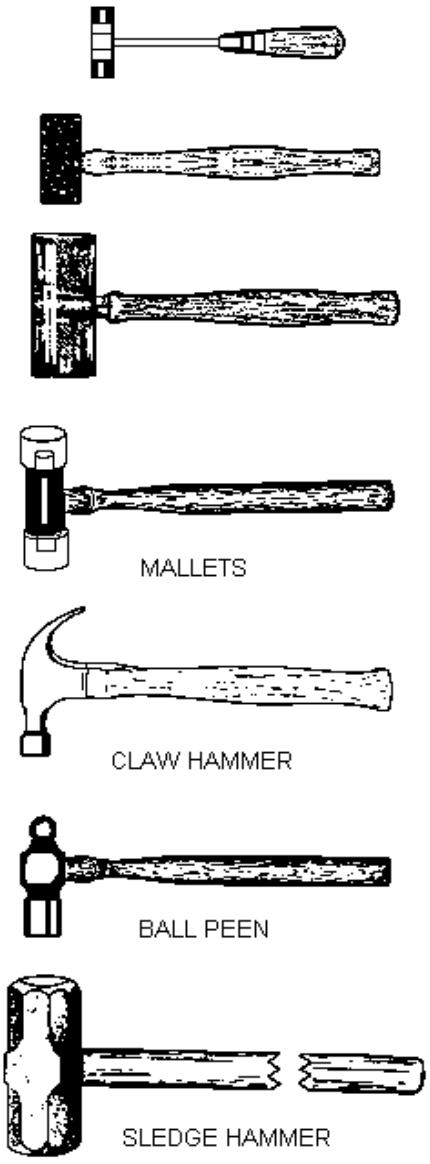


Figure 9, Hammers

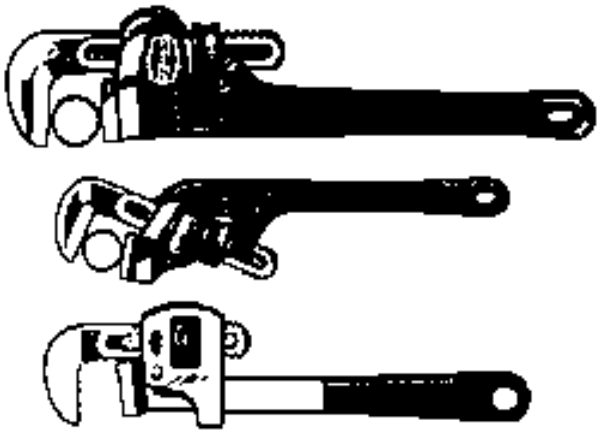


Figure 10, Pipe Wrenches

- **Adjustable Open-End Wrench.** The open-end adjustable wrench is a common tool used by most tradesmen. (See Figure 11). It is also the most misused tool of all and is commonly hammered on and even used backwards, as shown in Figure 11.

  The main precaution is to adjust the wrench so it will fit the nut or bolt head snugly so it will not slip and cause the edges of the nut to become rounded or burred when pressure is applied. The face of the jaws must be free of burrs and deep nicks. Adjustable wrenches are made so that their jaws can be opened or closed to fit the flats of a nut or bolt head. The size of the wrench is designated by its overall length.

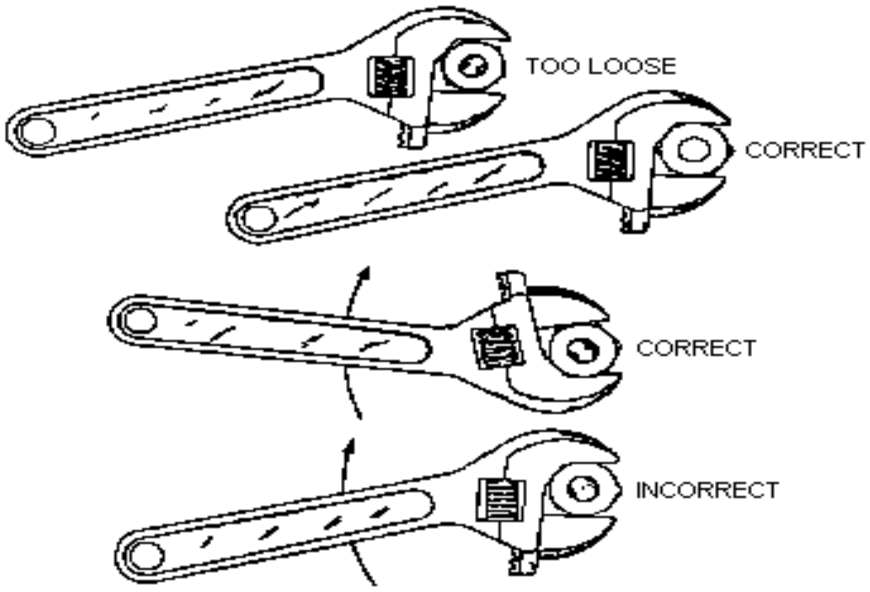


Figure 11, Adjustable Open-End Wrenches

NOTE:
Whenever using an adjustable wrench apply pressure against the fixed jaw of the wrench only (See Figure 12).

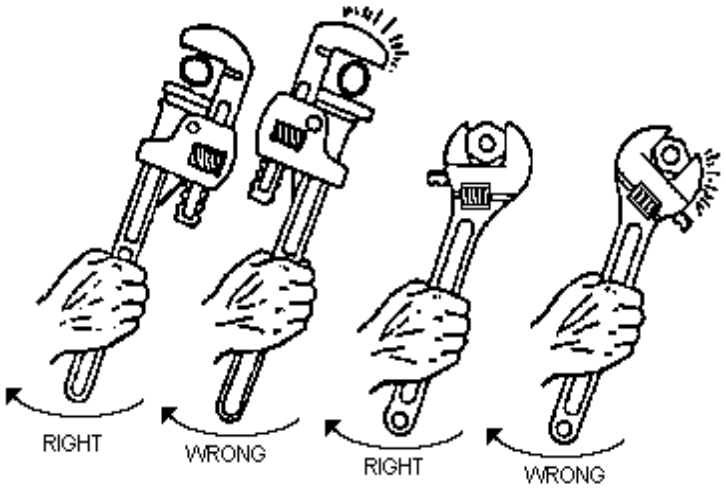


Figure 12, Open-End, Adjustable Wrench

- **Open End Wrench**. Open-end wrenches fit standard size nuts. They are lightweight, strong, and convenient for doing work in limited space. Because the jaws are set at an angle, usually 15° or 90°, it is easy to work in close places by turning the wrench over after each movement. The length varies according to the size of the opening. Some open-end wrenches are angular in construction. These are used in places where straight wrenches cannot be used. (See Figure 13).

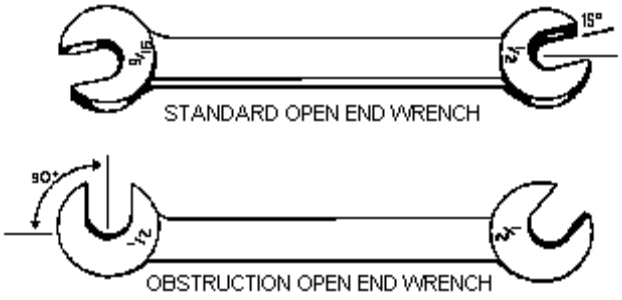


Figure 13, Open-End Wrench

- **Box End Wrench.** Box-end wrenches are used for general purpose work. These wrenches are well suited for operation in close places because their heads are small. They can be used on nuts that cannot be grasped with other types of wrenches. Most box-end wrenches have 12 points and most nuts have six sides; therefore, as little as one-twelfth of a turn can be taken each time the wrench is shifted. The length of the wrench varies according to the size of the opening (See Figure 14). Box-end wrenches should be used if possible in place of adjustable or open end wrenches.

All wrenches used by the HVAC/R mechanic should be kept in good condition. The ones showing any defects such as spread or distorted jaws, bent handles, or cracks, should be taken out of service. As mentioned previously, the tools must be kept clean and all moving parts oiled with light oil.

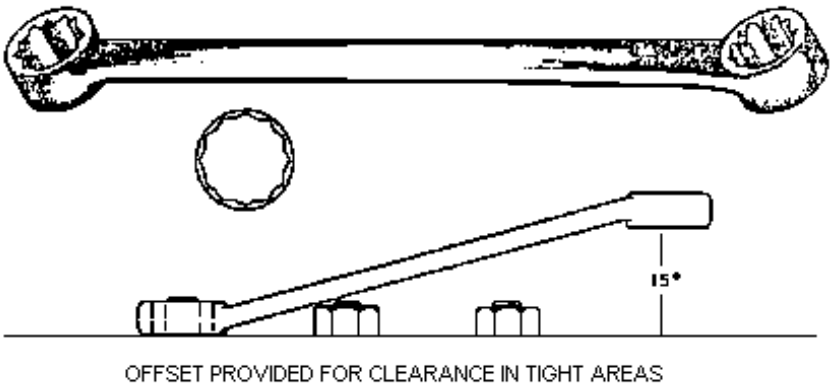


Figure 14, Box-End Wrench

- **Combination Open End, Box End Wrench.** The combination open end, box-end wrench has an open end at one end and a box end at the other end. Both ends will be the same size (See Figure 15).

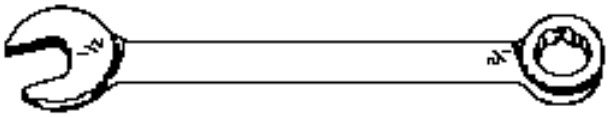


Figure 15, Combination Open-End and Box-End Wrench

- **Socket Wrenches**. Socket wrenches are frequently used where it is necessary to operate in close or hard-to-reach places. The sockets are supplied in sets to fit standard size nuts and are readily fitted onto or removed from the handle. A ratchet handle is usually included in the set so that the nut can be completely tightened without removing the socket from the work.

There are various other handles and attachments that go with a socket set to make it more versatile. (See Figure 16). The hinged handle (commonly called a breaker bar) and the sliding T-bar handle are used to loosen nuts which are extremely tight. The speed handle is used to remove or replace nuts quickly.

The universal socket or universal joints are used when you work at odd angles. It allows the socket to swivel or turn to fit the nut without changing position of the handle.

The extension bars come in several lengths used to extend your socket for nuts or bolts that are out of reach. The flexible extension will extend your socket as well as bend to fit an odd angle.

Another attachment sometimes used is the adapter. Socket handles come with different size drives. In other words, the end that fits the sockets has different sizes. Normally, the big sockets have larger drives than smaller sockets. The adapters are used to adapt a smaller socket to a larger drive handle or vice versa. The most common drives are: 1/4", 3/8", 1/2" or 3/4".

The screwdriver socket or screwdriver bits are another attachment used to turn your socket set into a screwdriver.

The last part of the socket set we need to talk about is the socket itself. Sockets come in almost any size desired. They also have different points, as shown in Figure. 16. The six point socket is the best to use for tight nuts and bolts because it won't slip. The 12 point socket will slip on real tight work but it works well in places where you do not have much room to move your handle. The deep socket is for nuts that have the bolt (the bolt the nut is attached to) extending up too far for the regular socket to reach it. The deep socket can grasp the nut and still have room inside for the bolt to extend up inside it (See Figure 17).

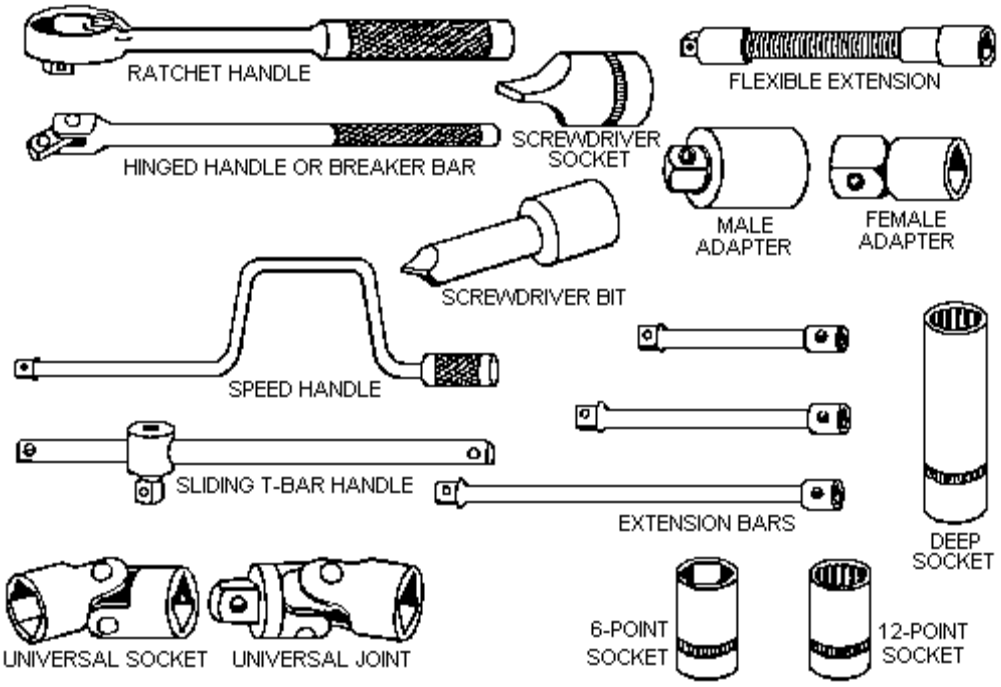


Figure 16, Socket Set

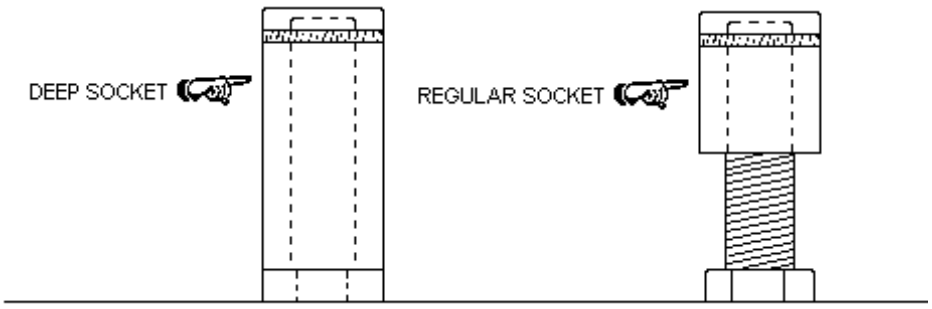


Figure 17, Deep and Regular Socket

Torque Wrenches. In some applications we may need to tighten a device to exact specifications. Some equipment needs to be tight, but over tightening could cause problems or damage. For this we use a torque wrench. The torque wrench is a handle that is used with a socket; however, the torque wrench can measure the amount of pull you put on it. On some torque wrenches a pointer indicates on a scale the amount of force being applied. This is called the bending beam type (See Figure. 18). Another torque wrench, called the dial indicator type, shows the amount of force used on a gauge. On the preset ratchet type you set a dial for the amount of torque desired

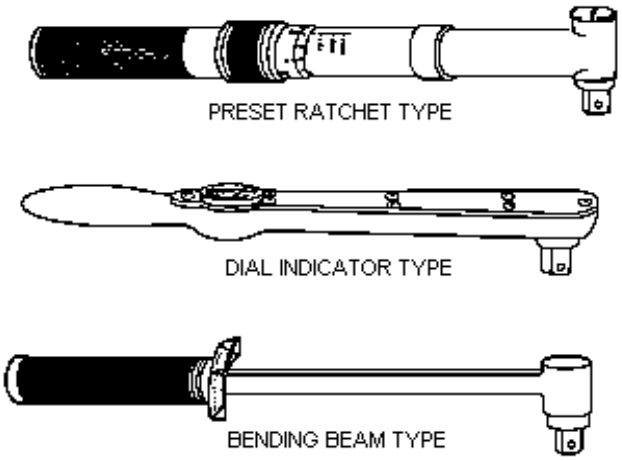


Figure 18, Torque Wrench

Allen Wrench. These wrenches are used for inserting and removing or installing set screws that have a hollow hex-shaped recess. This wrench commonly comes in sizes from 1/3 inch to 3/8 inch. (See Figure 19). They are also available in larger sizes.

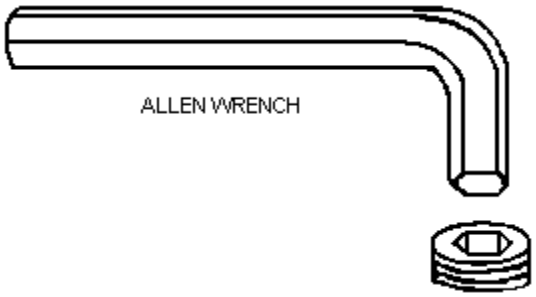


Figure 19, Allen Wrench

Files. A file is a hardened high-carbon steel tool for cutting, removing, smoothing, or polishing metal. A common file is shown in Figure 20.

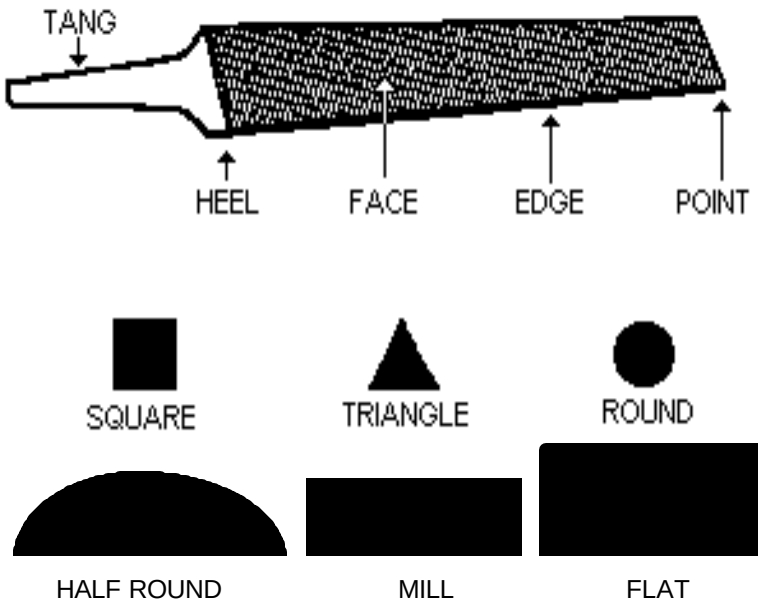


Figure 20, Files

The cutting teeth of files are made by a straight or diagonal rows of chisel cuts. Files are classified by name, grade, and cut. The cut may be either single or double. Grade refers to the distance between the parallel cuts. This is listed in the order of coarseness as follows: flat, course, bastard, second cut, smooth, and dead smooth. Files are made in various shapes and they vary from 3 to 24 inches in length. Always select the correct file for the work.

Using Files. *It is equally important for you to know how to use a file*. Here are some points to be observed when working with a file. Hold the file with the handle against the palm of your hand, thumb on top, and the end of the file in the other hand with your fingers curled under it. When filing, lean your body forward with the weight evenly distributed on both feet. Hold the file straight or the surface of the work will not be flat. Not more than 30 to 40 strokes per minute should be taken; too much speed will ruin the file and the work. Use pressure only on the forward stroke, and apply only enough pressure to make the file cut evenly. Lift the file from the work on the return stroke to prevent it from becoming dulled by scraping action. (This does not apply when filing very soft metals, such as lead or aluminum.) On soft work, pressure on the return stroke helps keep the file clean of removed metal.

Like all other tools, a file should be given good care while it is being used. Certain precautions should be carefully observed to get maximum results from filing. When filing soft metals, narrow surfaces, or working in corners, small particles of metal sometimes clog the teeth of the file and scratch the material being filed. This is called pinning. It is usually the result of putting too much pressure on the file, especially if it is a new one. To avoid pinning, be certain the file is "broken in" before taking heavy cuts. Also, rubbing chalk on the file before using it will help prevent pinning. A wire brush or file card can be used to clean the file. For best results and long life, use and store files properly.

Rules and Steel Tapes. There are many different styles and types of including:

- **Steel Rule.** The simplest measuring tool is the steel rule. Steel rules are non-flexible and are made in various lengths, usually six (6) or twelve (12) inches (See Figure 21).

- **Folding Rule.** The folding rule is available in lengths of six and ten feet. The HVAC/R mechanic must work carefully when unfolding the rule to prevent cracking or breaking the joints. If the joints become hard to operate, place a few drops of oil on each joint and remove excess oil with cloth. If the joints become excessively worn, you must be very careful or the joint will break when unfolding. Keep rule clean and protect the numbers at all times. A rule that has numbers which are not visible slows work progress(See Figure 21).

- **Flexible Steel Rule and Tape.** Flexible steel rules and tapes are used by the HVAC/R mechanic to measure short and long lengths of pipe or when laying out a job (See Figure 21). These flexible steel measuring tools must be kept clean and dry. Any dirt or sand on them tends to wear away the numbers and rust the steel. You must be careful when using the measuring tools to prevent kinking. A rule with a kink will not operate correctly. The bent part rubs against the housing when reeling the rule in and out, soon causing it to break. A very light oil should be used on the steel flexible measuring tools to keep them from rusting (See Figure 21).

- **Tri-Square and Combination Square.** The tri-square and combination squares are used to measure distances as well as angles. The tri-square consist of a steel rule with an extension at a 90° angle to the rule. The combination square is similar to the tri-square, but it has a moveable head (See Figure 21).

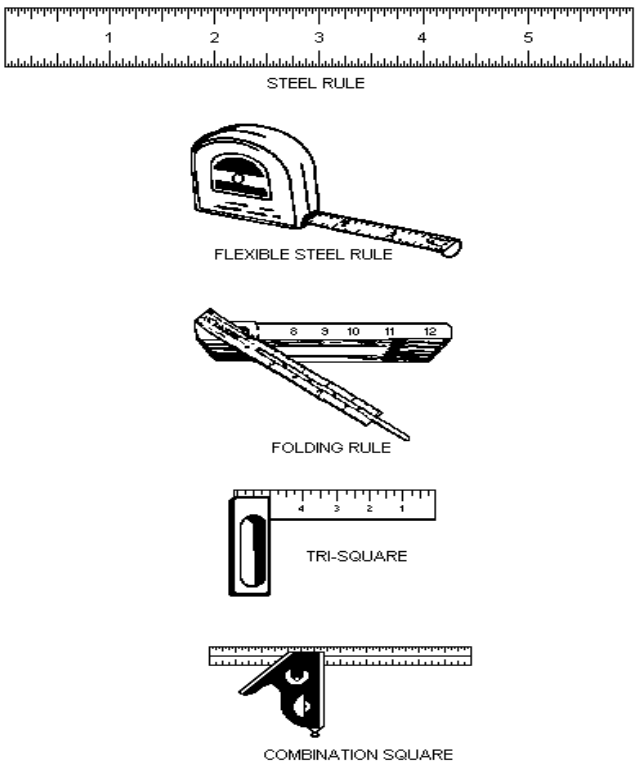


Figure 21, Rules and Tapes

Power Tools. Well will discuss only a few of the more common power tools you'll encounter throughout your career in this element. You should strive to learn more about power tools in other references and books as well.

- **Drill Press.** The drill press (See Figure 22) is a tool used for boring holes. It does the same job as the portable hand drill; however, the drill press is usually used for drilling into very hard or thick metals. When drilling hard or thick materials you should use cutting oil and maybe adjust the speed of the drill so as not to burn up the drill bit.

SAFETY:
When working with a drill press always wear goggles, turn the power off when making any adjustments, and always clamp down the material that you are drilling.

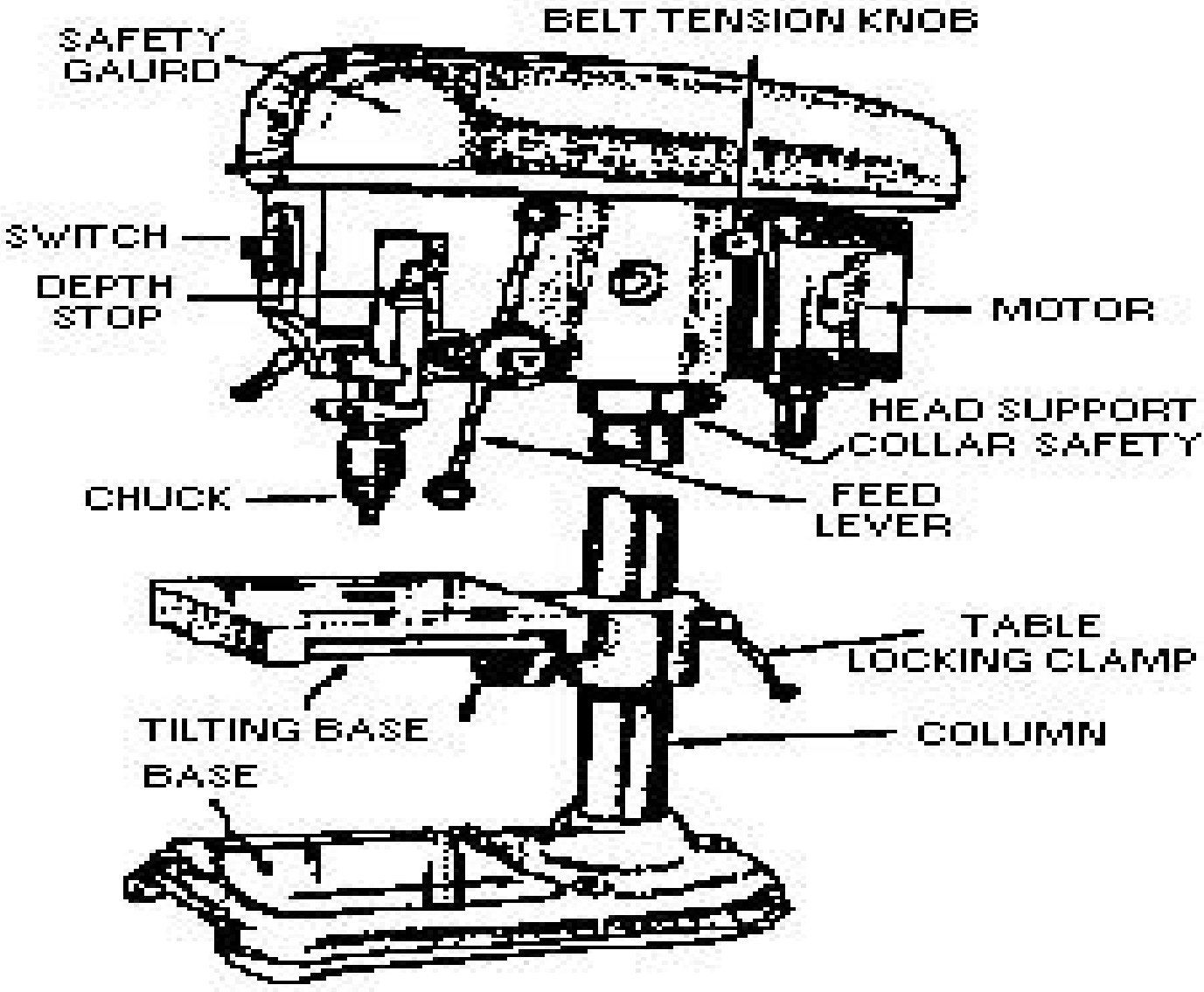


Figure 22, Drill Press

- **Portable Electric Drills.** Portable electric drills are used to make holes in either wood or metal. Be very careful when using an electric drill, especially the heavy-duty drill. All electrical connections must be grounded. Be very sure that you are standing firmly while drilling a hole with an auger bit. Occasionally, a nail is hit while drilling a hole and the drill will try to twist out of your hands. If it does, there is a good chance it will cause injury to you or someone else before it can be shut off.

  Geared Chuck. Ordinarily, straight shank drill bits are used in both the hand-operated electric drill and the electric drill stand. These bits are secured in a key type geared chuck. The geared chuck automatically centers the drill shank. Usually, the chuck is matched with a drill so that the chuck will open only wide enough to receive the maximum size drill bit for the motor. For example, a 1/4" electric drill will have a chuck that will take up to a 1/4" drill bit. The drill bit (See Figure 23) is classified by size in three ways: by numbers, letters, or fractions. The size will be stamped on the shank as shown in the drawing.

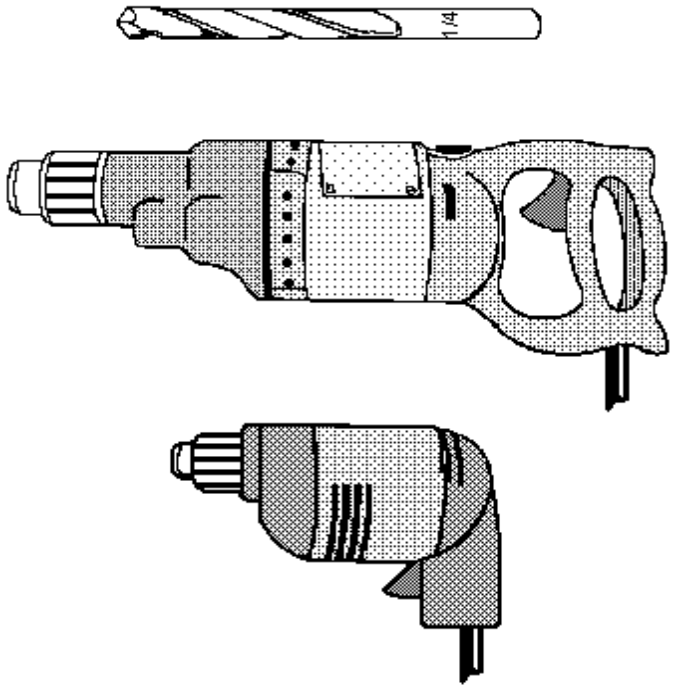


Figure 23, Portable Electric Drills

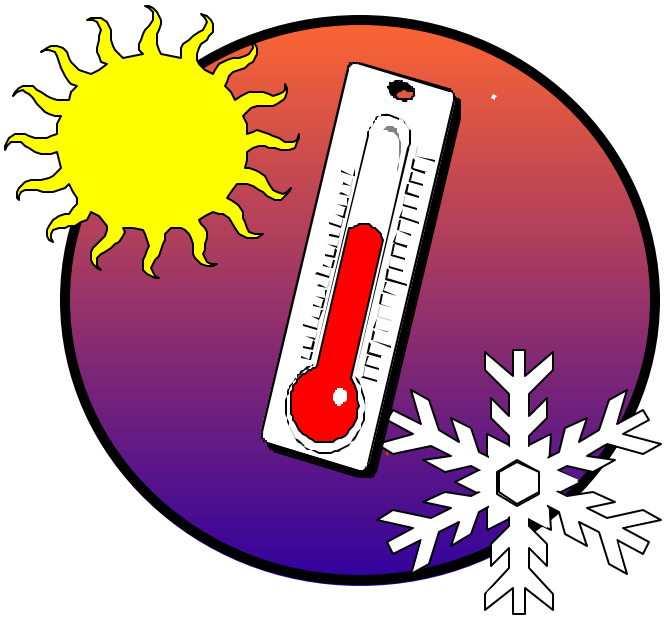
Review Questions
for
Maintain and Use Tools (Hand and Powered)

Question	Answer
1. Whenever using an _____ apply pressure against the fixed jaw of the wrench only.	a. Adjustable wrench b. Allen wrench c. Cats-claw d. Torque wrench
2. One of the most commonly used hand tools is the _____.	a. Screwdriver b. Allen wrench c. Claw hammer d. Socket wrench
3. Socket wrenches are frequently used in close, or hard to reach places.	a. True b. False
4. The Tri-square and Combination square are used to measure distances as well as angles.	a. True b. False
5. The _____is a tool used for boring holes.	a. Auger b. Military press c. Drill press d. Electric drill

MAINTAIN AND USE TOOLS (HAND AND POWERED)

Performance Checklist		
Step	**Yes**	**No**
1. Did trainee know the steps required to safely maintain tools (hand and powered)?		
2. Did trainee use Screw drivers properly?		
3. Did trainee use Pliers properly?		
4. Did trainee use Hammers properly?		
5. Did trainee use Wrenches properly?		
6. Did trainee use Files properly?		
7. Did trainee use Rules and Steel Tapes properly?		
8. Did trainee use Drill Press properly?		
9. Did trainee use Portable Electric Drills properly?		

FEEDBACK: Trainer should provide both positive and/or negative feedback to the trainee immediately after the task is performed. This will ensure the issue is still fresh in the mind of both the trainee and trainer.



TOOLS AND TEST EQUIPMENT

MODULE 11 AFQTP UNIT 3

MAINTAIN AND USE ELECTRICAL TEST EQUIPMENT (11.3.)

MAINTAIN AND USE ELECTRICAL TEST EQUIPMENT

Task Training Guide

STS Reference Number/Title:	11.3., Maintain and use Electrical Test Equipment
Training References:	• TR: AFI32-1064; T.O.s 32-1-101, 33A1-12-1
Prerequisites:	• Possess as a minimum a 3E131 AFSC
Equipment/Tools Required:	• Electrical Test Equipment • Personnel Protective Equipment • Standard HVAC/R Tool Bag
Learning Objective:	• The trainee will know the steps to safely maintain and use electrical test equipment
Samples of Behavior:	• Trainee will be able to safely maintain and use electrical test equipment
Notes:	
• Any safety violation is an automatic failure.	

MAINTAIN AND USE ELECTRICAL TEST EQUIPMENT

Background: We are aware that electricity cannot be seen. All that we can do is observe the results of electricity. When we see a light bulb glow, or an arc of lightning streak across the sky what we are actually seeing is a symptom caused by some sort of electrical discharge. Because of this property of electricity, many people are apprehensive, or even fearful of working with it. In this objective we will discuss how electricity can be safely measured and traced throughout circuits using electrical test equipment (meters).

Types and uses of Electrical Test Equipment. All three properties of electricity can be measured with meters. Voltage is measured with a voltmeter, resistance is measured with an ohmmeter, and current is measured with an ammeter. Knowing when and how to use these meters is vital to the survival and success of an HVAC/R technician.

Because meters are so important their integrity (accuracy, workmanship, and reliability) must be maintained. Many technicians make it a habit to carry at least two meters at all times just in case one fails, or renders a questionable reading. Great care should be taken when handling meters. Dropping or dragging meters could result in faulty readings, or failure to operate. Do not jerk, pull, or hang meters by their leads. This may result in breaking the conductor inside the insulation which would cause false readings. The batteries in meters should be checked and replaced periodically to insure that the meter will be ready when you need it. Meter neglect can lead to failure to get the job done, further equipment damage, or personal injury. It is in your best interest to ensure that meters are properly maintained.

Meters display their readings in two ways: Analog and Digital.

The procedures for using meters that have an analog display differ only slightly to those that have digital displays. For instance, most digital display meters have an "auto-ranging" feature that automatically sets the meter to the right scale when it is turned on. When using analog meters to check for resistance it is necessary to zero the meter prior to taking a reading, and this should be re-accomplished every time you change the range at which the readings are being taken.

There are advantages and disadvantages to both types of meters; however, the choice is yours, and it usually comes down to a matter of preference. Many believe that analog meters are more difficult to read, because there are many scales on the face of the meter. This is not really a problem, because once the technician becomes familiar with the different scales they can select the correct scale to acquire the appropriate reading. It is also important that you stand directly in front of the analog meter when taking a reading. Failure to do so will result in an inaccurate reading of the displayed value. Advances in electronics have led to the development of digital meters that are lighter, smaller, and more durable than analog meters. Glare from the sun or bright lights use to make it difficult for technicians to read digital displays, but with the development of liquid crystal displays much of that problem has been eliminated.

Some claim that digital meters are more accurate than analog meters, but that argument is greatly biased by a technicians ability to read an analog display. The bottom line is that both meters are comparable and the one you use will be the one that you are most comfortable with. The most important thing is to become familiar with your meter. Learn when and how to use all of the functions ,as well as, the limits of those functions on the meter that you are using.

Voltmeter. The voltmeter is used to measure the difference of potential between two points in volts. It is usually used to measure applied voltage, or voltage drops across a load. **Never** connect a voltmeter in series with the circuit, doing so will make the meter a load device and could result in meter failure or injury to the user. Voltmeters should be connected in parallel so that most of the current will pass through the load allowing the meter to measure the difference of potential between the two meter leads. The voltage range initially selected should be higher than the expected reading. If the voltage is unknown select the highest range.

Ohmmeter. The Ohmmeter measures resistance in ohms. It is also used to check electrical circuits or components for opens, shorts, continuity, and grounds. The most important factor when working with an ohmmeter is to ***ensure that the circuit is de-energized.*** Failure to do this will destroy the meter. All components being tested should be ***isolated*** from the rest of the circuit. The ohmmeter is **always** *connected in series* with the circuit or the component being tested. Because the ohmmeter has its own source of power (usually a battery), it can send a charge through the circuit on one lead and measure the result at the other lead. For an unknown resistive value, start with the lowest scale (R x 1) and work up until an accurate reading can be taken. The analog ohmmeter must be zeroed prior to use, and every time you change the range.

Ammeter. The Ammeter measures current flow in amps. It is connected in series with the circuit (Load), this way the current must flow through the meter as well as the load. To use an in-line ammeter the circuit must first be de-energized, so that the meter can be wired into the circuit. Once the meter is wired into the circuit, the circuit can be energized so that you can take the reading. This can be a very tedious and time consuming process if many readings must be taken. The clamp-on ammeter will get the same results as the in-line ammeter without having to de-energize, or break the circuit. This meter has a set of clamping jaws that can be spread apart and placed around a wire to measure the strength of the magnetic field around a wire. The jaws are opened and closed with the trigger located on the side of the meter. The clamp-on ammeter works because the intensity of the magnetic field around a conductor is directly related to the amount of current flow through the conductor. The meter then converts what it measures to an amperage reading. The clamp-on ammeter is much more convenient and is usually the ammeter of choice for HVAC/R technicians.

Multi-meters. Since voltmeters, ohmmeters and ammeters are all used to troubleshoot circuits, it follows that someone would combine the three into a single unit. Not only are they combined in one unit, which makes it convenient to carry all three meters, they are also portable (compact and light weight). Multi-meters were designed to be small and to contain their own power source for the ohmmeter function. Most of them have a power jack so that they can be used with an external power adapter to supply operating power, as well as, to charge the internal batteries.

Three of the most commonly used multi-meters in the HVAC/R career field today are the Simpson 260, the Fluke 77, and the Amprobe clamp-on. The following is a brief description of the three types:

- **Simpson 260.** The Simpson 260 is an analog multimeter. Figure 1 illustrates the different functions on the meter.

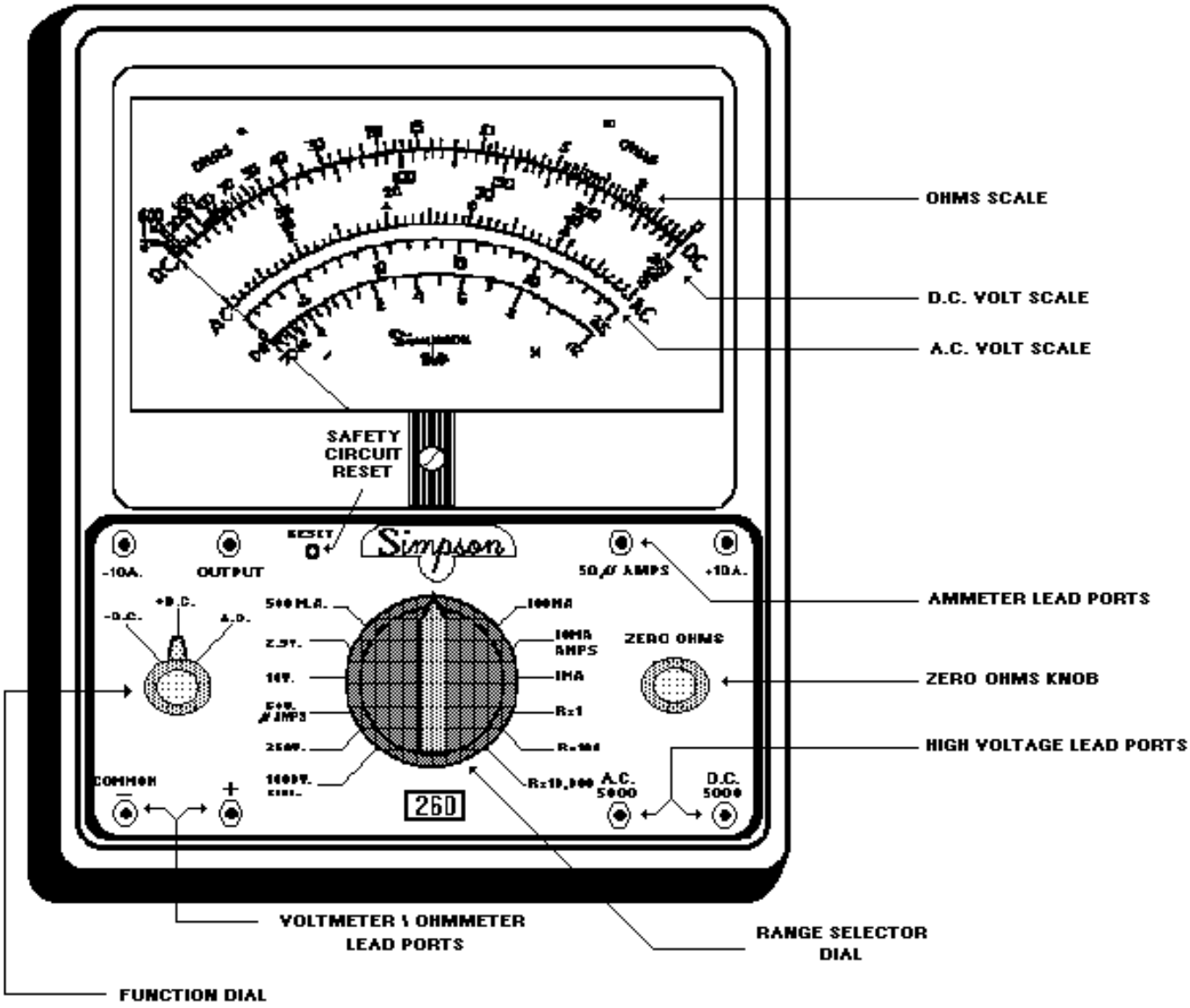


Figure 1, Simpson 260 Multimeter

Current Readings. The Simpson 260 multimeter was the meter most commonly used in our industry for a long-time. The procedures for using the different functions are as follows:

- Turn the function dial to the +DC function.
- Select the correct range to be used. 50 V (μ amps) for 50 ma or less readings, 10 amps for 10 amps or less readings.

NOTE:
This meter is only capable of measuring current up to 10 amps. This meters ammeter function is primarily used in electronic type circuits, and would not be commonly used by HVAC/R technician.

- Connect the meter test leads.
  - Red or Hot lead:
    - 5o µ amps port for measurements of 50ma or less.
    - 10A + ports for measurements of 10 amps or less.
  - Black or Common Lead.
    - The common (-) port for measurements of 50ma or less.
    - 10A - port for measurements of 10 amps or less.
- Ensure that the circuit or component is de-energized.
  - Open the circuit and place the tips of the leads on the open so that the meter is in series with the load.
  - Ensure that the only thing touching the circuit is the lead tips, and then energize the circuit.
  - Note where the needle on the display crosses the scale that you selected, this indicates the measured value. For current readings use the black DC scale.

Voltage Readings.

- Turn the function dial to select the type of voltage you intend to measure.
- Select the correct range to be used.
- Connect the meter test leads to the connections located at the bottom left of the meter.
  - Red or Hot lead:
    - This lead is placed in the "+" port.
  - Black or Common Lead
    - This lead is placed in the common (-) port.
    - Place the tips of the leads on the circuit so that the meter is in parallel with the load.
  - Ensure that the only things touching the circuit are the lead tips, and that the lead tips are touching only that part of the circuit that you are measuring.
  - Note where the needle on the display crosses the scale that you selected, this indicates the measured value.

NOTE:
You should always select a range that is higher than the expected reading. This prevents the needle from "pegging" which can damage the meter.

Resistance Readings. Turn the function dial to select the +D.C. function.

- Select the correct range to be used.
- Connect the meter test leads to the connections located at the bottom left of the meter.
  - Red or Hot lead:
    - This lead is placed in the "+" port.
  - Black or Common Lead
    - This lead is placed in the common (-) port.
- Place the tips of the two leads together and turn the zero ohms knob until the meter is zeroed.
- Ensure that the circuit or component being tested is de-energized and isolated.
- While holding the insulated handles of the leads, place the tips of the leads on the circuit or component that you are testing, so that the meter is in series.
- Note where the needle on the display crosses the scale that you selected, this indicates the measured value.

NOTE:
Do not place your fingers on the tips of the leads when taking a reading. Doing so will alter your readings.

Interpreting the Scales. As stated earlier the objection to using analog meters stems from the fact that the technician has to select the correct scale and interpret the point at which the needle and the scale intersect. Although this is an additional step, with a little practice, the technician can become as proficient at reading the analog meter as they are at reading the digital meter. Figure 2 is an illustration of the scales on the Simpson 260 multimeter.

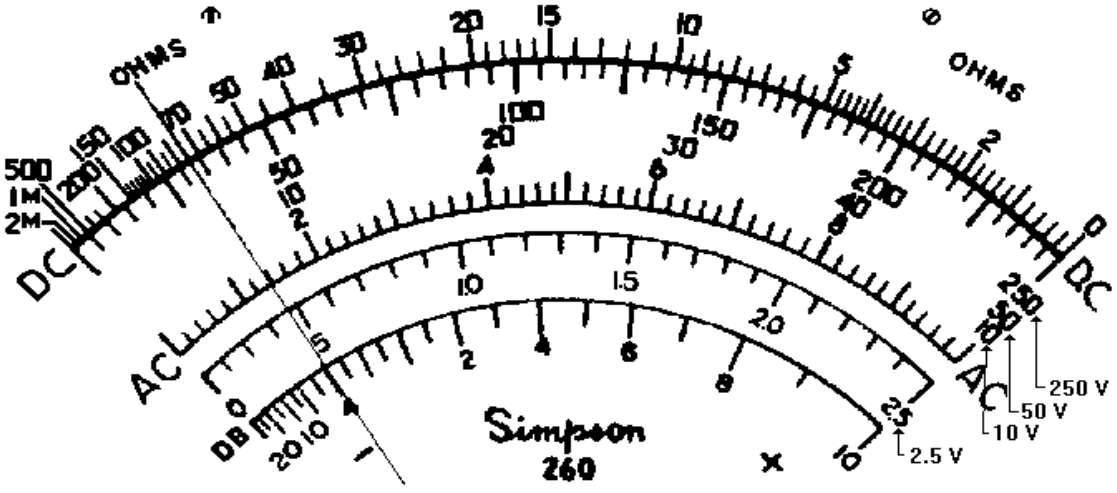


Figure 2, Scales found on the Simpson 260

Reading Scales. The key to reading these scales is just a matter of locating the scale that corresponds with the range and function that is selected when the meter is set-up for taking the reading. The next step is to then identify where the needle crosses that scale. For example, if the function dial was set on +D.C. , and the range dial was set at the 10 V range, the scales in Figure 3 would be indicating a difference of potential equal to 1.3. However, if the function dial was set at A.C. , and the range dial was set at the 1000 V range, the scale in Figure 3 would be indicating 120. Let's do an example.

If the function dial is set on A.C. , and the range dial was set on the 250 V range, what would the scales in Figure 3 be indicating?

Step 1: First think to yourself "What is the meter set to measure", this will tell you what scale to take your reading off of. The function dial is set on A.C. so that means that we will use the A.C. scale.
Step 2: Then ask yourself "Within what range is the meter set to take this reading", this tells you what range on the A.C. scale to use. The range switch was set on 250 V, so we will take our reading off the 250 volt range on the A.C. scale.
Step 3: The next step is simply locating where the needle crosses the scale that you selected. In this case the needle crosses the A.C. scale at the seventh hash mark.
Step 4: Because all of the hash marks are not labeled you will have to figure out the value of each hash mark. A task easily accomplished once the nearest major hash marks are identified.

The tenth hash mark is a value of 50 (using the 250 V range on the A.C. scale), so the fifth hash mark is understood to be 25 because it's in the middle of 0 and 50. Based on this we see that there is a change of 25 between the major hash marks, and that it is divided into 5 increments. This indicates that every hash mark (increment) represents a change of 5. So, if the fifth hash mark is 25, and the needle crosses the scale at the seventh hash mark, we can quickly interpret the reading to be 35. All units for this example would be Volts, A.C.

This seems like a long and complicated process but once the technician gets use to the scales, much of the interpretation will be automatically done subconsciously. The only way to be proficient at taking readings with this type of meter is to practice, so here are some practice problems.

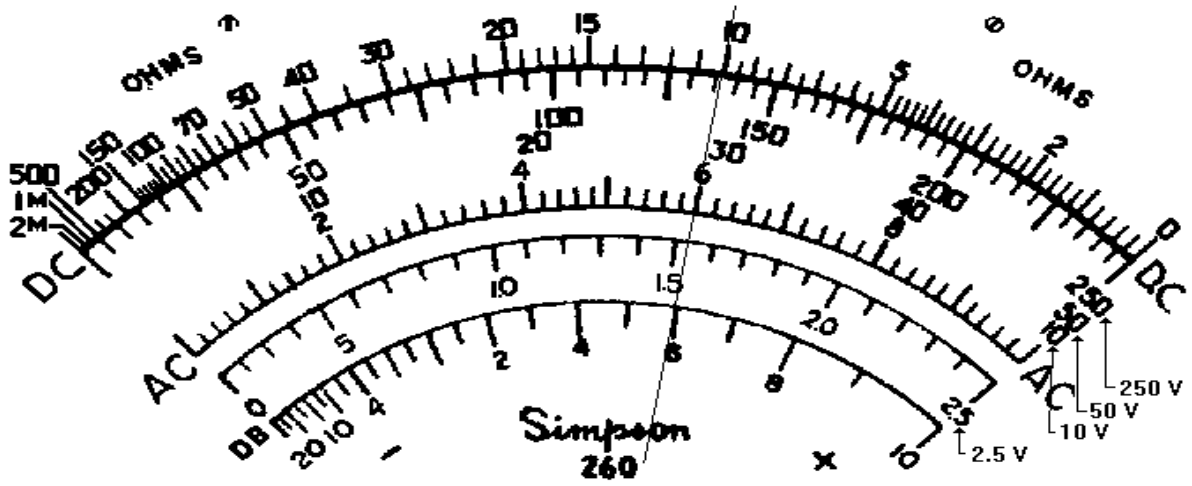


Figure 3, Scales found on the Simpson 260

Problem #1.

If the Function Dial was set on +D.C. , and the range dial is set on:

Range dial = **10 V**: The meter indicates: 5.4 vac _____

50 V: The meter indicates: _____

250 V The meter indicates: _____

Problem #2.

If the Function Dial was set on A.C. , and the range dial is set on:

Range dial = **2.5 V**: The meter indicates: _____

10 V: The meter indicates: _____

50 V: The meter indicates: _____

250 V: The meter indicates: _____

- **Fluke 77.** The Fluke 77 is a digital multimeter. Figure 4 illustrates the different functions on the meter.

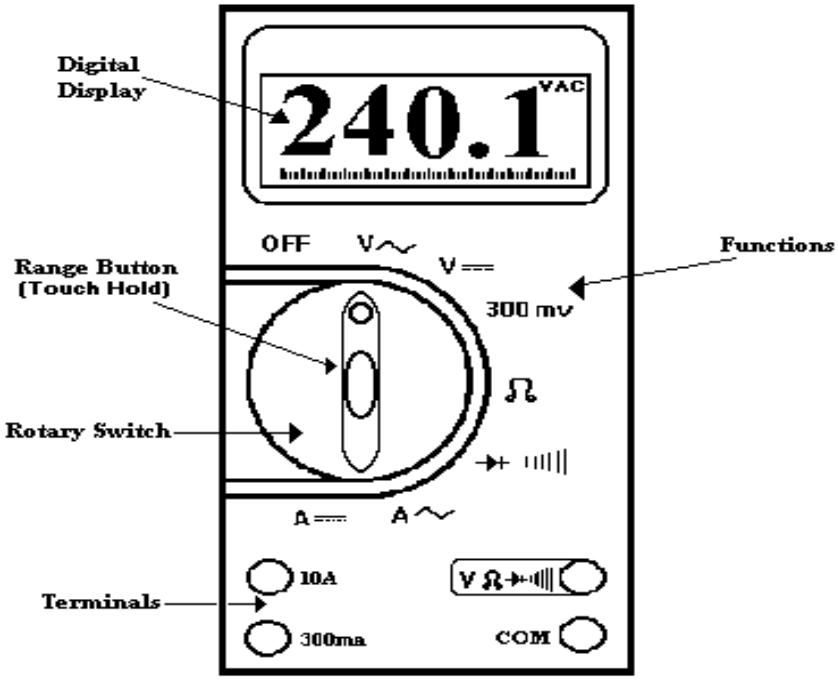


Figure 4, Fluke 77 Digital Multimeter

The Fluke digital multimeter is the meter most widely used in our industry at this time. The procedures for using the different functions are as follows:

Current Readings.

NOTE: There are two ammeter functions:
- One for DC current (A---).
- One for AC current (A~), be sure to select the appropriate function for the circuit that you are working on.

Meter is auto ranging, which means that the meter will automatically select the correct range to be used.

- Turn the function dial to select the ammeter function.
- Connect the meter test leads to the connections located at the bottom of the meter.
    - **Red or Hot lead**
        - There are two ports for checking current.
        - 10A port for measurement of 10 amps or less, or up to 20 amps for no more than 30 seconds.
        - 300ma port for measurements of 320 milli-amps or less.
    - **Black or Common Lead**
        - This lead is placed in the COM port.
- Ensure that the circuit or component is de-energized.
- Open the circuit and place the tips of the leads on the open so that the meter is in series with the load.
- Ensure that the only thing touching the circuit is the lead tips, and then energize the circuit.
- View the display and de-energize the circuit. Remember; for measurements greater than 10 amps, the meter should not be in the circuit for more than 30 seconds.

NOTE:
Both ranges for current readings have fuses inside of the meter to protect the meter from damage caused by over-current applications. To test for a blown fuse, simply take the tip of the common lead and insert it into either the 10A port or the 300mA port. If the meter displays O.L. at either port the fuse for that circuit is blown. For good fuses the display should read .3 ohms or less for the 10A port and 4 to 8 ohms for the 300mA port.

Voltage Readings.
- Turn the function dial to select VAC or VDC depending on what type voltage you are measuring .
- Connect the meter test leads to the connections located at the bottom of the meter.
    - **Red or Hot lead**
        - This lead is placed in the, (voltage, V Ω ⊣+ ohms, and continuity).

  - **Black or Common Lead**
    - This lead is placed in the COM port.

- Place the tips of the leads on the circuit so the meter is in parallel with the load.
- Ensure the only things touching the circuit are the lead tips, and that the lead tips are touching only that part of the circuit that you are measuring.
- View the display.

Resistance Readings.

- Turn the function dial to select the ohmmeter function (Ω).

NOTE:
This meter is auto ranging, which means that the meter will automatically select the correct range to be used.

- Connect the meter test leads to the connections located at the bottom of the meter.
  - **Red or Hot lead**
    - This lead is placed in the (voltage,  ohms, & continuity port).
  - **Black or Common Lead**
    - This lead is placed in the COM port.
- Ensure that the circuit or component being tested is de-energized and isolated.
- While holding the insulated handles of the leads, place the tips of the leads on the circuit or component that you are testing, and read the value on the display.

This multimeter is also equipped with a diode checker. The diode checker allows the technician to check the bias of a diode, or if the diode is shorted. Diodes are commonly associated with electronic components, and since HVAC/R technicians do not generally work on electronic circuitry, we will not use this feature in this manner very much. However, we can use this feature to do continuity checks.

Continuity Check.

- Turn the function dial to select the diode check (continuity) function.
- Connect the meter test leads to the connections located at the bottom of the meter.
  - **Red or Hot lead**
    - This lead is placed in the (voltage,  ohms, & continuity port).

- **Black or Common Lead**
  - This lead is placed in the COM port.

- Ensure that the circuit or component being tested is de-energized and isolated.

- While holding the insulated handles of the leads, place the tips of the leads on the circuit or component that you are testing. If there is a continuous path for current to flow between the leads, the meter will beep continuously. If there is an open in the circuit between the leads, the meter will remain silent.

Amprobe Clamp-On. The Amprobe Clamp-on is an analog multimeter. Figure 5 illustrates the different functions on the meter.

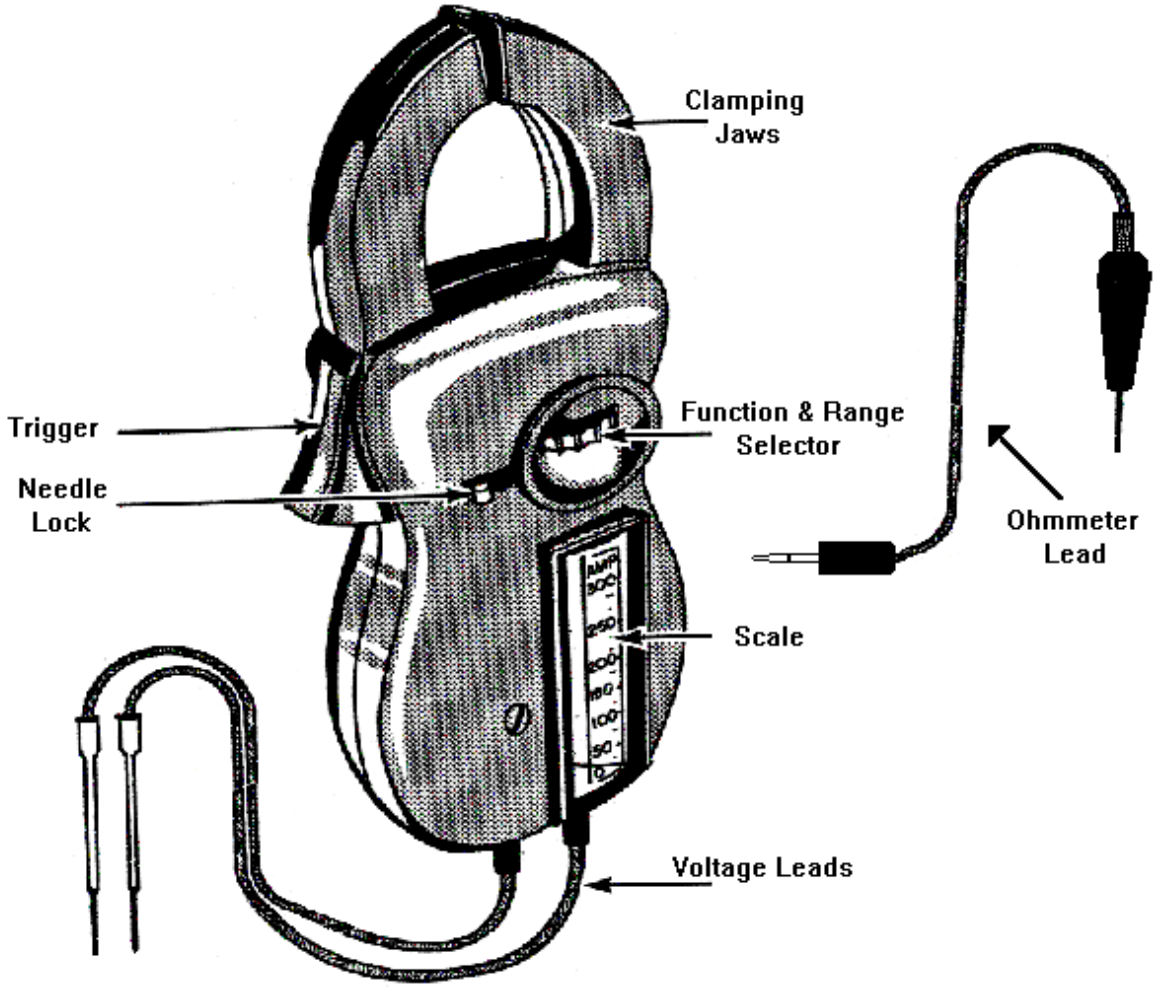


Figure 5, Amprobe Clamp-on Multimeter

The Amprobe clamp-on multimeter is primarily used for taking current readings; however it is capable of taking voltage and resistance readings as well. The procedures for using the different functions are as follows:

Current Readings.

- Turn the function dial to select an amperage scale greater than the expected reading.
- Ensure that the needle lock switch is in the unlocked position.
- Squeeze the trigger to spread the clamping jaws, and place the conductor to be tested inside of the jaws.
- Release the trigger allowing the clamping jaws to close around the conductor being tested, and read the value off of the scale.

NOTE:
If the conductor is located in a space where it is difficult for the technician to read the scale, simply lock the needle in place by switching the needle lock switch to the locked position. This can be done as soon as the clamping jaws have been placed around the conductor. Once the needle has been locked in place the meter can be removed from around the conductor, and viewed where the technician can accurately read the scale.

Voltage Readings.

- Turn the function dial to select a voltage scale greater than the expected reading
- Ensure that the needle lock switch is in the unlocked position.
- Connect the voltage leads to the connections on the bottom of the meter
- While holding the insulated handles of the voltage leads, place the tips of the leads on the circuit or component that you are measuring, and read the value on the scale.

Resistance Readings.

- Ensure that the needle lock switch is in the unlocked position.
- Connect the special ohmmeter lead to the connection on the right side of the meter.
- Connect the common lead to the connection on bottom of the meter
- Place the tips of the two leads together and turn the calibration dial on the side until the meter is zeroed.
- Ensure that the circuit or component being tested is de-energized and isolated.
- While holding the insulated handles of the leads, place the tips of the leads on the circuit or component that you are testing, so that the meter is in series, and read the value on the scale.

NOTE:
The resistance scale on the Amp probe clamp-on multi-meter is a fixed scale, and is automatically selected when you use the ohmmeter lead.

Review Questions
for
Maintain and Use Electrical Test Equipment

Question	Answer
1. A voltmeter should be connected in a _____ circuit?	a. Parallel b. Series c. Phase d. Ground
2. If the voltage on a circuit is unknown, a higher range than needed should be selected prior to taking a voltage reading with an analog voltmeter.	a. True b. False
3. What will an ohmmeter indicate across an open switch?	a. Finite b. Definite c. Infinity d. A broken circuit
4. What is the best meter to use when there is a short?	a. Ampere meter b. Odometer c. Fluke meter d. Ohmmeter

MAINTAIN AND USE ELECTRICAL TEST EQUIPMENT

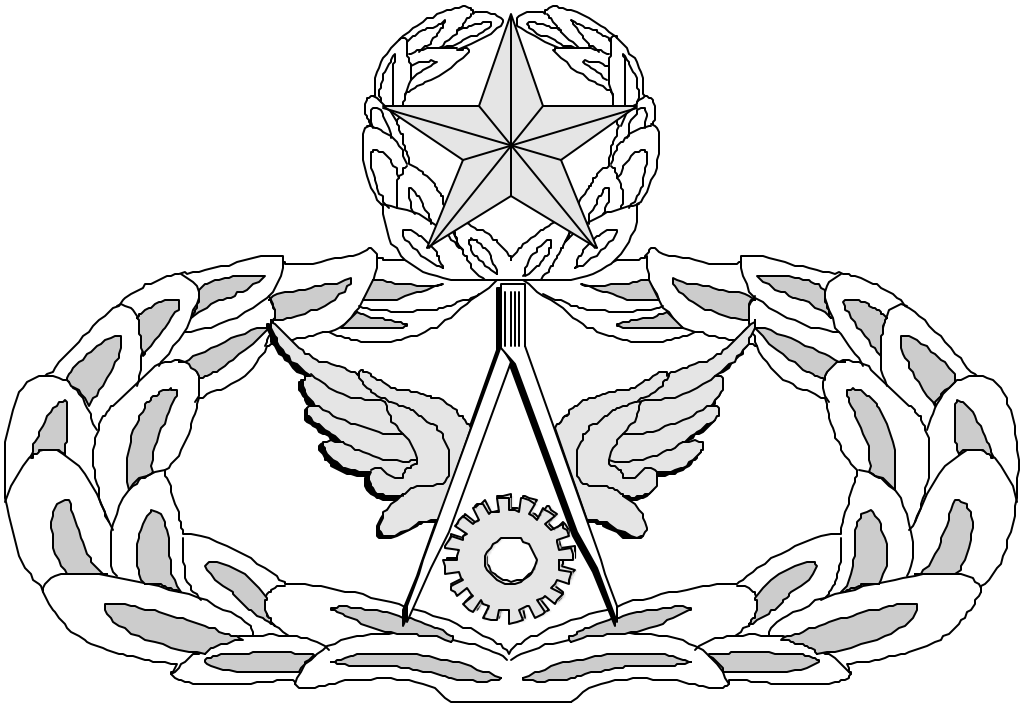
Performance Checklist		
Step	**Yes**	**No**
Operational Test		
1. Did the trainee successfully perform the following tasks with the Voltmeter?		
a. Safety		
b. Parallel Connection with Circuit		
c. Readings with Voltmeter		
2. Did the trainee successfully perform the following tasks with the Ohmmeter?		
a. Safety		
b. Series Connection with Circuit		
c. Readings with Ohmmeter		
3. Did the trainee successfully perform the following tasks with the Ammeter?		
a. Safety		
b. Circuit must be de-energized		
c. Readings with Ammeter		

FEEDBACK: Trainer should provide both positive and/or negative feedback to the trainee immediately after the task is performed. This will ensure the issue is still fresh in the mind of both the trainee and trainer.

Air Force Civil Engineer

QUALIFICATION TRAINING PACKAGE (QTP)

REVIEW ANSWER KEY



For

HVAC/REFRIGERATION

(3E1X1)

MODULE 11

TOOLS AND TEST EQUIPMENT

Notice. This AFQTP is *NOT* intended to replace the applicable technical references nor is it intended to replace hands-on training. It is to be used in conjunction with these for training purposes only.

MAINTAIN AND USE TOOLS (HAND AND POWERED)

(3E1X1-11.1.)

Question	Answer
1. Whenever using an _____ apply pressure against the fixed jaw of the wrench only.	a. Adjustable wrench
2. One of the most commonly used hand tools is the _____.	a. Screwdriver
3. Socket wrenches are frequently used in close, or hard to reach places.	a. True
4. The Tri-square and Combination square are used to measure distances as well as angles.	a. True
5. The _____is a tool used for boring holes.	c. Drill press

MAINTAIN AND USE ELECTRICAL TEST EQUIPMENT

(3E1X1-11.3.)

Question	Answer
1. A voltmeter should be connected in a _____ circuit?	a. Parallel
2. If the voltage on a circuit is unknown, a higher range than needed should be selected prior to taking a voltage reading with an analog voltmeter.	a. True
3. What will an ohmmeter indicate across an open switch?	c. Infinity
4. What is the best meter to use when there is a short?	d. Ohmmeter